CHAPTER 2

KNOWLEDGE REPRESENTATION AND INFERENCE

Requirements for K.R. Languages

- Representational adequacy:
  It should allow to represent all knowledge that one needs to reason with.

- Inferential Adequacy:
  It should allow new knowledge to be inferred from basic set of facts.

Requirements for K.R. Languages (Cont.)

- Inferential Efficiency:
  Inferences should be made efficiently.

- Naturalness:
  The language should be reasonably natural and easy to use.

Requirements for K.R. Languages (Cont.)

- Clear Syntax and Semantics:
  We should clearly define allowable formulas (and the language) and their meaning.

Syntax and Semantics

- Syntax (Symbols):
  Formal Language = Set of Symbols.
- Semantics (Meaning):
  Is the Meaning (of all symbols).

Syntax and Semantics (Cont.)

- Example 1:
  - K. Represent : Propositional Logic.
  - Syntax: p q
  - p and q are non logical sentences.

(Continued on Next Slide)

Syntax and Semantics Example 1 (Cont.)

– Classical Propositional Logic Semantics:

- If light goes on, then bring a towel.
  p : light goes on,
  q: bring a towel

- p is True or False.
  q is True or False.

□	T	F
T	T	F
F	T	T

Syntax and Semantics (Cont.)

- We say:

$$A \text{ True} \quad \text{iff} \quad \models A$$

- Example:

$$(p \;\square\; q) = \text{True} \quad \text{iff} \quad \models (p \;\square\; q)$$

Syntax and Semantics (Cont.) Example 2

- Example 2 for Syntax and Semantics:
  - Syntax: (p □ q)
  - p = 2+2 = 4
    q = 273
  - (T □F) = F
  - Hence, (p □ q) is False in this particular case.

Syntax and Semantics (First Order Logic)

- Example (Book):

Red(Allison, Car) ≡ Allison's car is red.
(Intended Interpretation)

- Red – Two argument predicate symbol.
- Alison – Constant
- Car – Constant.

$P(C_1, C_2)$

Syntax and Semantics Book Example (Cont.)

- Question !
  (About the knowledge Representation):

  Is Red (as a color) always a 2−argument relation?
  What about "Red (flower)" with intended semantics.

- But it may be ok in your particular program, if well defined and used consistently – Always define your syntax and semantics – It is formal and not intuitive !!!

Syntax and Semantics Book Example (Cont.)

- We can have two knowledge Representations for "Alison's car is Red."

- Knowledge Representation 1:
  - Red(Allison, Car)
  - Here we have a predicate of the form: P (C_1, C_2), i.e., two argument predicate.
  - Pure Logic: Red(x,y) $\leftrightarrow$ x has a Red y.

Syntax and Semantics Book Example (Cont.)

- Knowledge Representation 2:
  - Check book, page 10.
  - Red(x) $\leftrightarrow$ x is red. (Different semantics !)
  - Constant: Allisons−car.
  - Red(Allisons−car).
  - Pure Logic: P(C).
    - P is one argument predicate.
    - P(x) is one argument predicate.
    - $P_{\underline{r}}$: Red (Intended Interpretation.)

Syntax and Semantics Book Example (Cont.)

- The following two representations should not appear together !

1) □x Red (x, house)
   This means some people have a red house.

2) □x Red (x)
   This means some x (object) is Red.

Naturalness

- A Knowledge Representation language should allow you to represent adequately complex facts in a clear, precise and natural way.
- Use Intended Semantics. (Refer back to Block World)
- Some facts are hard to represent in a way that we can also correctly reason with them.

Naturalness (Cont.)

- Example:

  John believes no-one likes brussel sprouts.

  - Believes - ??
  - Syntax: Bel (x,y)
    Semantics: x believes in y
  - What are rules that govern our believe system?
  - Believe Logics, Modal Logics, etc.
  - We are out of first order logic.

Clear Syntax and Semantics

SYNTAX ⟷ SEMANTICS

- A precise syntax and semantics are particularly important given that an AI program will be Reasoning with the knowledge and drawing new conclusions.

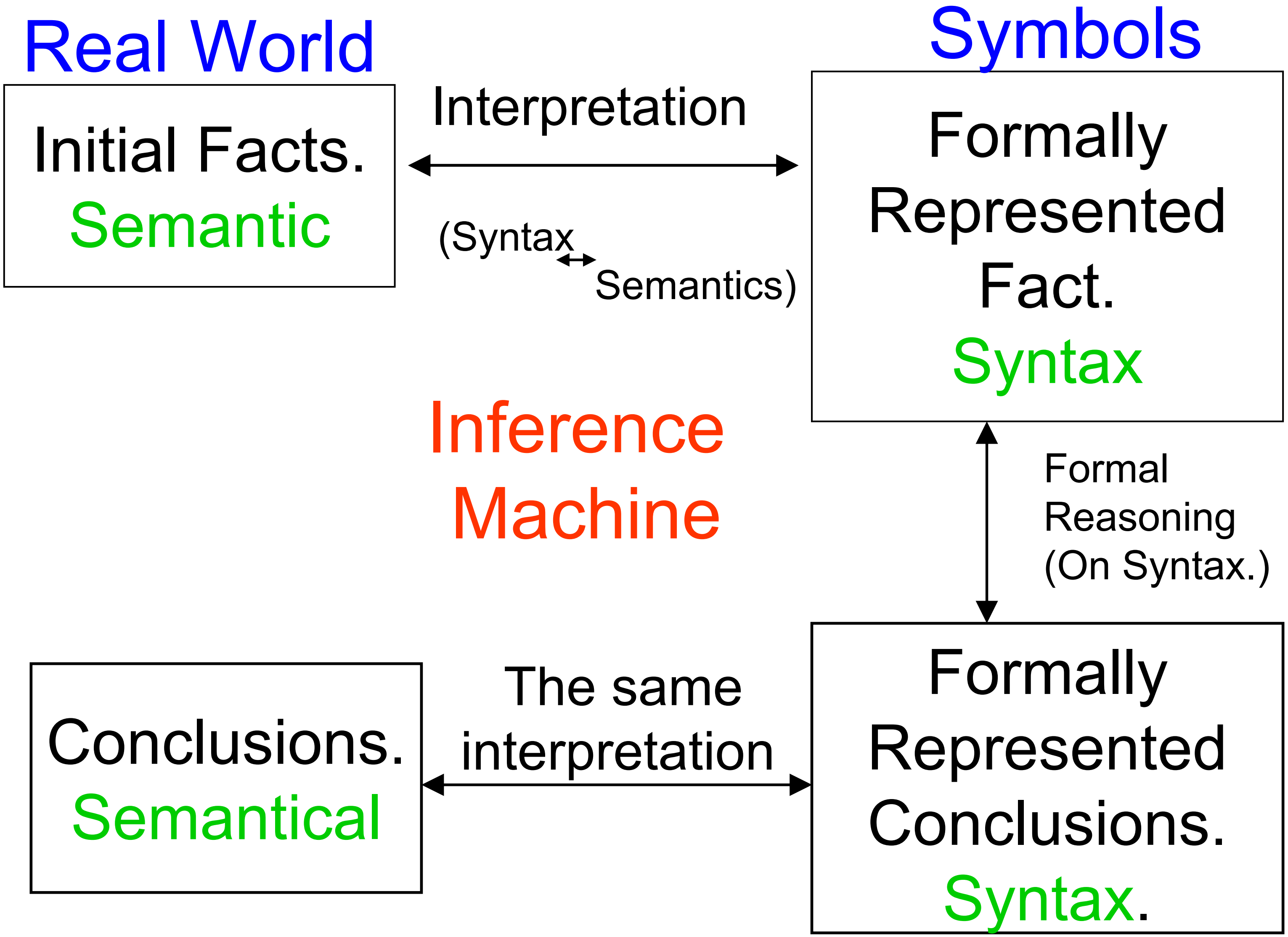
Clear Syntax and Semantics (Cont.)

- Example:
  If system concludes:
  "Interest (Alison, high)"
  we need to know what it means !

  Does it mean:
  - Allison's Mortgage interest is high.
  - I am interested highly in Allison.
  - Or maybe... Allison is interested in high mountains climbing.

  And all this under Intended Interpretation.
  Interest(x,y) iff "x is interested in y"

Syntax – Semantics Picture



Inferential Adequacy

- Being able to deduce new facts from existing knowledge.
- Knowledge Representation Language Must Support Inference.
- Point:
  We can’t represent explicitly everything that the system might ever need to know; Some things must be left implicit to be deduced when needed.

Inferential Adequacy (Cont.)

- Example:
  Let us say we have Knowledge about a 100 students. It is wasteful to record all facts about all students (in one database.)
  - We can deduce that Fred attends (some) lectures from the fact that Fred is a student, etc.
  - Fred cannot be the president of the u.s – We deduce it from the fact that u.s. has a president and it is not Fred, etc.

Main Approaches to Knowledge Representation

- Logic.
- Frames and Semantic Networks (Nets).
- Rule – Based Systems.

Main Approaches to Knowledge Representation

- Logic:
  Declarative approach and classical reasoning. Classical logic $\longmapsto$ non-classical logics: temporal, modal, belief, fuzzy, intuitionistic and many others.

Main Approaches to Knowledge Representation

- Frames and Semantic Networks (Nets):
  - Natural way to represent factual knowledge about classes of objects and their properties.
  - Knowledge is represented as a collection of objects and relations.
    The special relations are: Subclass and Instance, and we define the property of Inheritance.

Main Approaches to Knowledge Representation

- Rule – Based Systems:
  - Procedural aspects of our knowledge are stressed more than the declarative ones.
  - Condition – Action rules are widely used in Expert Systems.
  - A Rule – Based language provides algorithms for reasoning with such rules.

Main Approaches to Knowledge Representation

- Rule – Based Systems (Cont.):
  - Rule – based systems are also called Production Systems.
  - They were first introduced by E. Post in 1944.
  - Current form is due to A. Newell & H.A. Simon (1972) **for psychological modeling.**
  - B. Buchanan & E. FEIGENBAUM (1978), **Cannot see !**